THE ECONOMIC IMPLICATIONS OF WATER EROSION IN ALBERTA

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THE ECONOMIC IMPLICATIONS OF WATER EROSION

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FOREWORD

Soil loss due to water and wind erosion is recognized as a major problem in areas of rural Alberta. Alberta Agriculture places significant emphasis on conservation and management of soil and water resources employed in agricultural production. This study has taken a theoretical approach to measure potential direct effects on farm costs of water erosion in agricultural areas. It provides a conservative estimate of soil loss due to water amounting to $88.7 million per annum. The report clearly illustrates the high pay-off to be gained from improved soil and water conservation practices, and the need for increased research and commitment in these areas.

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ABSTRACT

This study used modelling techniques to estimate the theoretical water erosion potential in Alberta under different soil cover types. Potential soil losses were estimated from data stored in the SOILEROS datafile. Soil lost was assumed to be removed from the affected field and redeposited in watercourses or water bodies. Dollar values were attributed to potential topsoil loss estimates on the basis of the three main nutritive elements in the soil. Results were presented graphically through the Geographic Data Processing and Plotting System. The mean potential erosion calculated using the existing municipal crop mixes, was 4.9 tonnes per hectare per year. This is equivalent to a value of 88.7 million dollars, based on the cost of replacing the nutrients (N, P and K) lost from the area occupied by the dominant soil and landform in each area examined. This loss is equivalent to 2.3 per cent of the 1984 provincial gross farm cash receipts or 3.3 per cent of farm cash operating expenses.

INTRODUCTION

For quite some time water erosion has been rated as a basic concern in agriculture. The cumulative effects of contemporary intensive agricultural practices have been highlighted in reports such as "Soil at Risk: Canada's Eroding Future".[1] Such reports have brought the erosion issue to the forefront. The awareness of both the public and agricultural planners regarding potential losses due to soil erosion has been heightened. Erosion control is now perceived as taking a more important role in the future viability of agriculture in Alberta. There is an increased emphasis on the conservation and management of soil and water resources in the province as evidenced by a number of provincial programs as well as support for or cooperation with federal programs.

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1. "Soil At Risk: Canada's Eroding Future", A Report on Soil Conservation by the Standing Committee on Agriculture, Fisheries, and Forestry, To The Senate of Canada. Hon. H. O. Sparrow, Chairman.

Unfortunately, there is little quantitative information currently available on this subject. The goals of this paper are:

1. to estimate the physical importance and distribution of erosion potential under various crop management schemes; and

2. to estimate the direct and indirect cost of such erosion to the economy of Alberta.

METHODOLOGY

The methodology used in this study involved the merging of four sets of data. These were: statistics on the concentration of the three main nutritive elements (nitrogen, potassium and phosphorus)[1]; prices for these elements[2]; the C-Factor values[3]; and soil loss estimates stored in the SOILEROS datafile[3]. The value of top soil was estimated using a nutritive equivalent measure. Potential soil loss values and cost of soil loss were computed for several cropping and management combinations. Results were processed through the Geographic Data Processing and Plotting System (GDPP)[4] to obtain a graphic presentation of economic and physical costs of water erosion in Alberta. Results obtained represent averages for individual townships.

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1. Soils Branch, Alberta Agriculture - personal communication.

2. Andruchow, Lloyd, Production & Resource Economics Branch, Alberta Agriculture - personal communication.

3. Tajek, J.; Pettapiece, W.W. and Toogood, K.E., 1985. Water Erosion Potential of Soils in Alberta: Estimates Using a Modified USLE. Agriculture Canada Technical Bulletin No.1985-29, Ottawa. 35 pp.

4. Kao and Associates Consulting Ltd. 1983. The Geographic Plotting Systems: User Guide.

THE SOILEROS DATAFILE

The SOILEROS file contains soil loss data in tonnes per hectare (t/ha) associated with bare soil and soil under wheat for the area covered by soil survey maps. The data file was developed by linking elements of the Universal Soil Loss Equation (USLE)[1] to a computerized land database SIDMAP[2]. The size of individual cells in the SOILEROS database was set at one section to accommodate the detail of available information used in assessment of some USLE factors. Computer programs with the SOILEROS database made it possible to merge additional information such as the C-factor and to compute soil loss for specific cropping or management systems.

THE UNIVERSAL SOIL LOSS EQUATION (USLE)

The USLE is a model of soil erosion designed to predict long term averages of soil loss caused by water erosion for a specific field under specific cropping and management systems. Precipitation intensity, soil and topographic parameters, as well as cropping and management practices (including summerfallow), are used for computation of soil loss estimates. Several modifications have been made to the procedures used in estimating individual factors of USLE by Tajek, Pettapiece and Toogood (1985). This was done to reflect specific climatic and topographic conditions in Alberta. This equation has not been extensively tested under Alberta conditions, however, it appears to be the best model of water erosion available to Alberta researchers. The equation used to

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1. Wischmeier, W. H. and Smith, D.D. 1965. Predicting Rainfall Erosion Losses from Cropland East of the Rocky Mountain. Guide for Selection of Practices for Water Conservation. Agric. Handbook no. 282.

2. Patterson, G.T.; Peterson, G.E. 1984. Soil Inventory Database for Management and Planning (SIDMAP): Database. Agriculture Canada, Soil Survey, Edmonton. Memo. 12 pp.

compute soil loss in the SOILEROS datafile is:

A = RT.K.LS.C.(.P)

where:

A = Average annual soil loss t/ha.

Rt = Total precipitation factor (MJ mm/ha/h), includes the combined erosivity of rainfall and spring runoff (based on snow on the ground at the time of thaw).

K = Soil erosivity (based on physical properties and pedogenic development of soil series recognized in Alberta).

LS = Topography (combines the effect of slope steepness and slope length associated with typical landforms in Alberta).

C = Cropping factor computed for various crops, based on typical cropping and management practices as well as the monthly distribution of the Rt factor in various geographic regions of Alberta.

P = Conservation practices (no value was assigned).

Computed soil loss values in the SOILEROS datafile represent potential erodibility for the dominant soil and landform in specific one section cells. Currently available information for assessment of individual factors of USLE as well as the level of detail in SIDMAP permits calculations of soil loss only for the dominant soil in each cell.

ECONOMICS OF EROSION

Using the SOILEROS file, statistics were generated for each ground cover type, by municipality. The ground cover factor (C) was derived to reflect the existing practices, including summerfallow, used with the selected ground cover. Five basic ground cover types were included in the analysis; these being: no ground cover, small grains, canola, alfalfa and forest with a poor canopy. It is obvious that none of these individual ground cover types apply equally to the whole province. For example, forest cover is not applicable to the dry south, while there are climatic limitations to the growing of small grains and canola. However, the use of no ground cover and forest cover provided the two extremes of erosion potential.

The alfalfa cover may be the most applicable and could represent other grass cover types, including native pasture. This cover type is not, however representative of the actual situation in Alberta. To provide more representative cover categories, two additional cases were generated by weighting the crop cover types firstly, by the provincial crop mix and secondly, by the municipal level crop mixes. In each case the percentage of summerfallow in the rotation was reflected in the ground cover factor (c).

The provincial crop mix was derived from a weighted average crop mix for the agricultural area of the province and was applied to every municipality. The mix included the average proportion of summerfallow acreage for the whole province. The municipal level crop mix was different for each municipality and was based on the average crop mix reported for each municipality. It included the proportion of summerfallow acreage in each municipality. The average provincial crop mix is provided in Table 1. The municipal crop mix is not provided since it was different for each municipality.

An economic estimate of the cost of erosion was derived using the value of top soil. This value was determined using the cost of fertilizer which would be required to replace the nutritive elements in

TABLE 1

PROVINCIAL CROP MIX FOR AGRICULTURAL LANDS OF ALBERTA

Crop	Distribution[1] (%)
Alfalfa[2]	33.0
Canola	6.3
Small Grains	60.6

1. Per cent of cropped acreage, including summerfallow acreage in the rotation.
2. Includes hay and improved pasture.

the lost soil. Though this estimate is incomplete in that it does not acknowledge the structural and other values of the soil, it is based on presently available physical information.

Analysis was confined to the three main nutritive elements: nitrogen, potassium and phosphorus. Statistics at the municipal level regarding the amount of available potassium and phosphorus were obtained from the Soils Branch of Alberta Agriculture. Specific statistics were not available regarding the amount of available nitrogen. However, they were extrapolated from organic matter data which were available for each soil zone (Table 2).[1] Average nitrogen values were obtained by weighting these organic matter levels by the proportion of each soil type per municipality.

The average value of a tonne of soil for each municipality in Alberta was obtained by costing the relative quantities of each nutritive element in the soil (Table 3). Fertilizer prices were used to determine

1. Lickacz J. and Penney D., Soil Organic Matter, Alberta Agriculture, Agdex 536-1.

TABLE 2

ORGANIC MATTER IN NATIVE AND CULTIVATED SOILS

Soil Zone	Virgin (Native) Soil (%)	Cultivated Soil (%)
Brown	3-4	2-3
Dark Brown	4-5	3-4
Black	6-10	4-6
Dark Gray	4-5	2-3
Gray	1-2	1-2

Source: Lickacz J. and Penney D., Soil Organic Matter, Alberta Agriculture, Agdex 536-1.

TABLE 3

MARKET VALUES OF NUTRITIVE ELEMENTS

Nutritive Element	Cost[1] ($/tonne)
Nitrogen	616.84
Potassium	242.33
Phosphorus	550.75

1. Cost as of September, 1985.

the costs. The estimated cost to the farm community was calculated by combining the fertilizer or nutritive costs with the physical erosion potential.

The data base used in the estimation of erosion potential contained information on the dominant portion of each section of land. No information was available on the non-dominant portion. The first estimate assumed the nutrient levels of any given area to be equivalent to that of the dominant soil and landform of that area. A correction factor was applied to adjust the cost estimates for the non-dominant portion of land. The corrected or adjusted values were derived as a proportion of the initial estimated cost equivalent to the proportion of the area occupied by the dominant soil and landform (Table 4).

TABLE 4

WEIGHTED MEAN PROPORTION OF DOMINANT SOIL AND LANDFORM BY REGION

Region	Weighted[1] Mean (%)
1	88
2	84
3	80
4	83
5	70
6	70

1. Percentage of area with the dominant soil and landform characteristics used to adjust the initial estimates.

This correction for the non-dominant portion of land, permitted the estimation of the cost of erosion on the dominant portion for which the data available are most representative. Such an estimate may represent the case in which it is assumed that all non-dominant lands are either deposition areas or areas which are not adversely affected by erosion.

RESULTS

PHYSICAL

As shown in Table 5, the mean potential water erosion level for agricultural lands ranged from 24.9 tonnes per hectare per year (t/ha/yr) with no ground cover (continuously), to 0.1 t/ha/yr for a forest cover with a poor canopy. The municipal crop mix, which is a relatively close representation of the existing situation, produced a mean potential water erosion level of 4.9 t/ha/yr. This was lower than that produced by the use of the provincial crop mix (5.3 t/ha/yr). This does indicate that there is some (direct or indirect) adaptation in crop mix at the regional level to reduce erosion potential. The crop mix in individual municipalities is marginally better than the average provincial crop mix in terms of soil conservation.

There was a substantial amount of variation in potential erosion between Administrative Regions. With the provincial crop mix, Region 6 had the highest potential erosion level, followed by Regions 3 and 5. Region 6 is also different from the other regions in that the mean potential erosion level is higher with the municipal crop mix than with the provincial crop mix. There is therefore room for reducing erosion potential in Region 6 by altering the crop mix, providing climatic conditions permit this change.

When shifting the basis of the analysis from agricultural lands to all surveyed lands, there is a general tendency to higher erosion potential, except for Region 2 (Table 6). This would indicate that lands which have not yet been included in the agricultural land base are more erosion prone than those which are presently being farmed.

TABLE 5

MEAN WATER EROSION POTENTIAL BY REGION AND GROUND COVER TYPE[1] FOR AGRICULTURAL LANDS

Region	No Ground Cover	Canola	Small Grains	Provincial Crop Mix	Municipal Crop Mix	Alfalfa	Poor Canopy Forest
	(tonne/ha/yr)						
	19.2	8.1	6.1	4.5	4.6	0.5	0.1
2	23.8	10.0	7.2	5.2	5.4	0.6	0.1
3	29.0	10.7	8.1	5.8	4.9	0.7	0.1
4	19.8	6.7	5.4	4.0	3.9	0.5	0.1
5	28.4	9.7	7.7	5.5	3.6	0.7	0.1
6	31.8	12.2	9.2	6.6	7.2	0.8	0.2
Alberta	24.9	9.6	7.3	5.3	4.9	0.6	0.1

1. Weighted by the distribution of agricultural lands.

TABLE 6

MEAN WATER EROSION POTENTIAL BY REGION AND GROUND COVER TYPE[1]
FOR ALL SURVEYED LANDS

Region	No Ground Cover	Canola	Small Grains	Provincial Crop Mix	Municipal Crop Mix	Alfalfa	Poor Canopy Forest
	(tonne/ha/yr)						
1	20.5	8.6	6.7	4.7	4.8	0.5	0.09
2	22.5	9.4	6.9	4.9	5.0	0.6	0.10
3	37.3	13.8	10.5	7.5	5.3	0.9	0.17
4	21.9	7.5	6.0	4.3	3.9	0.5	0.10
5	47.2	16.1	12.9	9.3	4.4	1.2	0.24
6	35.7	13.1	10.1	7.6	7.5	0.9	0.18
Alberta	31.3	11.5	8.9	6.4	5.5	0.8	0.15

1. Weighted by the distribution of all surveyed lands.

The provincial distribution of erosion potential, calculated for the average municipal crop mix, is shown in Figure 1. It is seen that the frequency of potential erosion exceeding 11 t/ha/yr is low (15 per cent of cases) and is usually restricted to the foothills (west), the Cypress Hills (southeast) and river valleys. With small grains monoculture (Figure 2) there is an increased occurrence of erosion potential above 11 t/ha/yr (24 per cent of cases). There is also the potential for erosion above 22 t/ha/yr (13 per cent) and even above 33 t/ha/yr (5.6 per cent). This last situation occurs mostly in the Foothills and Cypress Hills. With no ground cover, the area affected by erosion levels higher than 33 t/ha/yr increased to 25.8 per cent. The area affected by potential erosion levels smaller than 11 t/ha/yr fell to 39 per cent (Figure 3).

ECONOMIC

The annual potential cost of water erosion, based on loss of nutrients on the existing agricultural land base, ranged between 2.4 million and 531.6 million dollars, depending on what ground cover assumption was used (Table 7). If it is assumed that the municipal crop mix represents the existing situation, the annual potential cost of the erosion would be approximately 108.9 million dollars. When the correction factor for non-dominant soil and landform was applied, the cost decreased to 88.7 million dollars (assuming that the non-dominant portion was not subject to erosion).

To put this cost in perspective it can be compared with farm cash receipts or cash operating expenses in Alberta. As seen from Table 7, the corrected cost of the erosion potential (under the municipal crop mix cover) is equivalent to 2.3 per cent of the gross farm cash receipts of the province or 3.3 per cent of cash operating expenses. By comparison, wages paid to farm labor represented 5.0 per cent of gross farm cash receipts or 7.3 per cent of cash operating expenses. Realized net income of 634 million dollars (gross receipts less cash operating expenses and depreciation) represented 16.1 per cent of gross cash receipts. These estimates show that if nutrients lost through erosion

WATER EROSION POTENTIAL FOR SOILS IN ALBERTA

CALC. FOR MUNI. CROP MIX

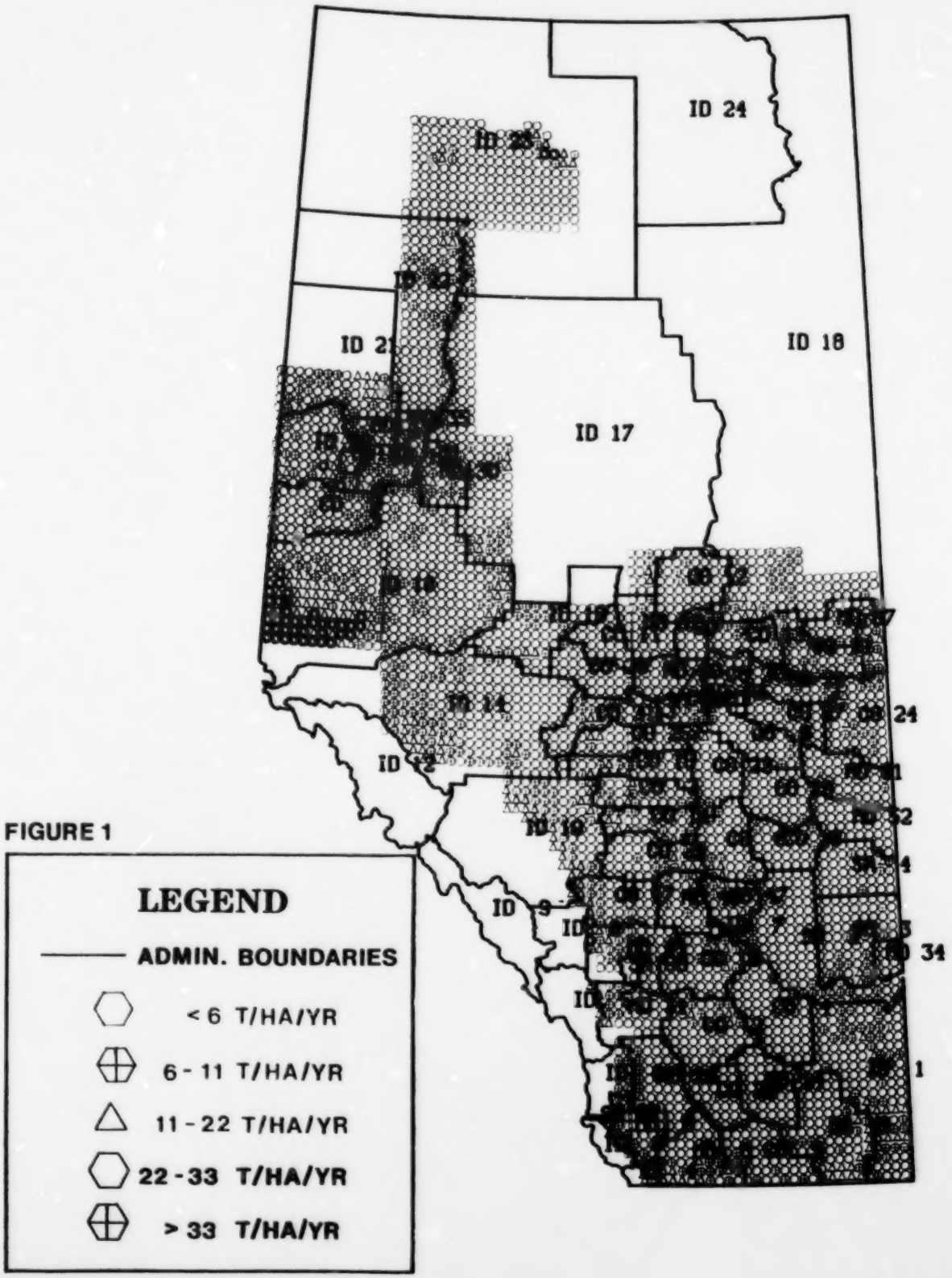

FIGURE 1

WATER EROSION POTENTIAL FOR SOILS IN ALBERTA

CALC. FOR SMALL GRAINS

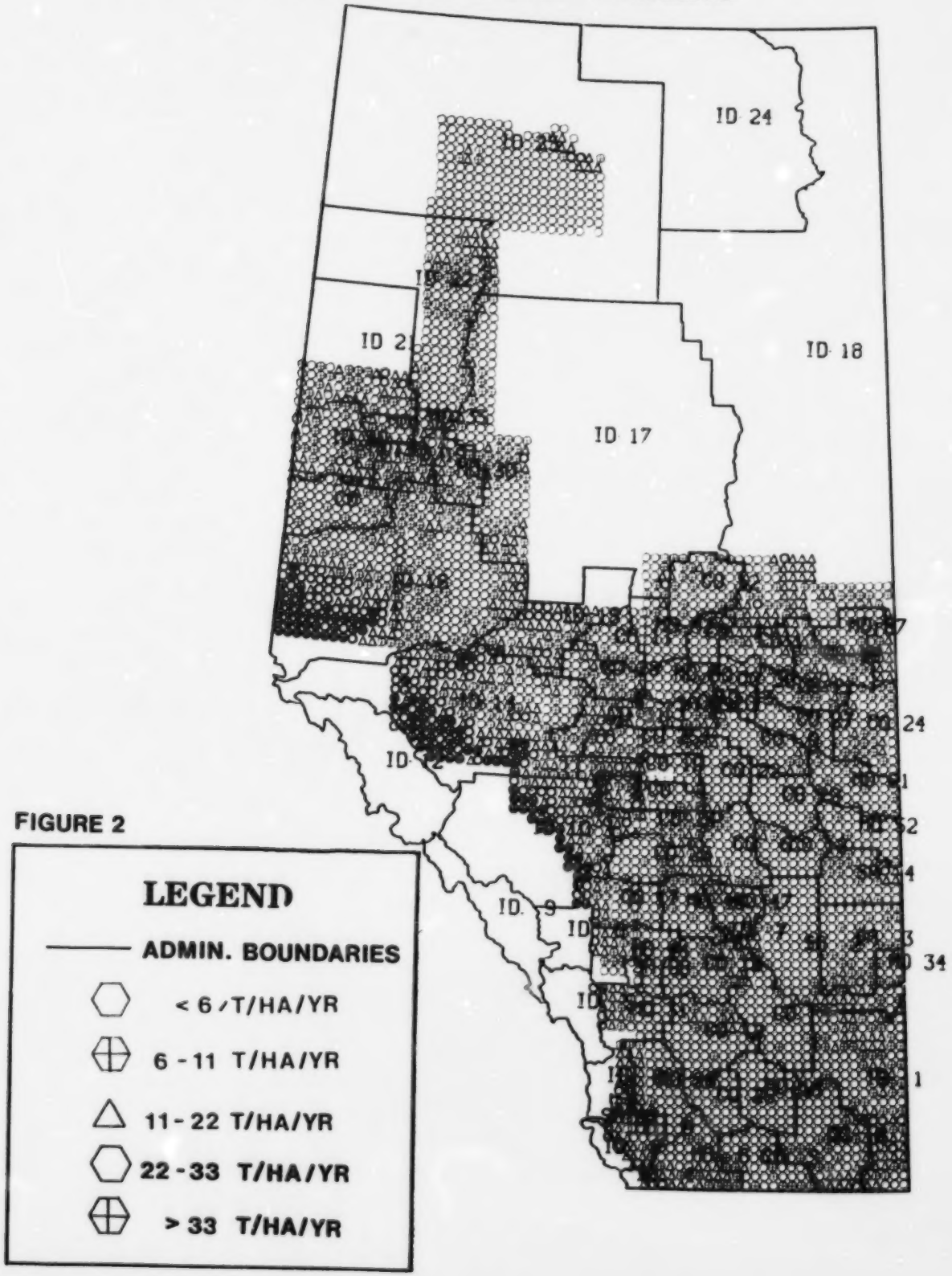

FIGURE 2

WATER EROSION POTENTIAL FOR SOILS IN ALBERTA

CALC. FOR NO GROUND COVER

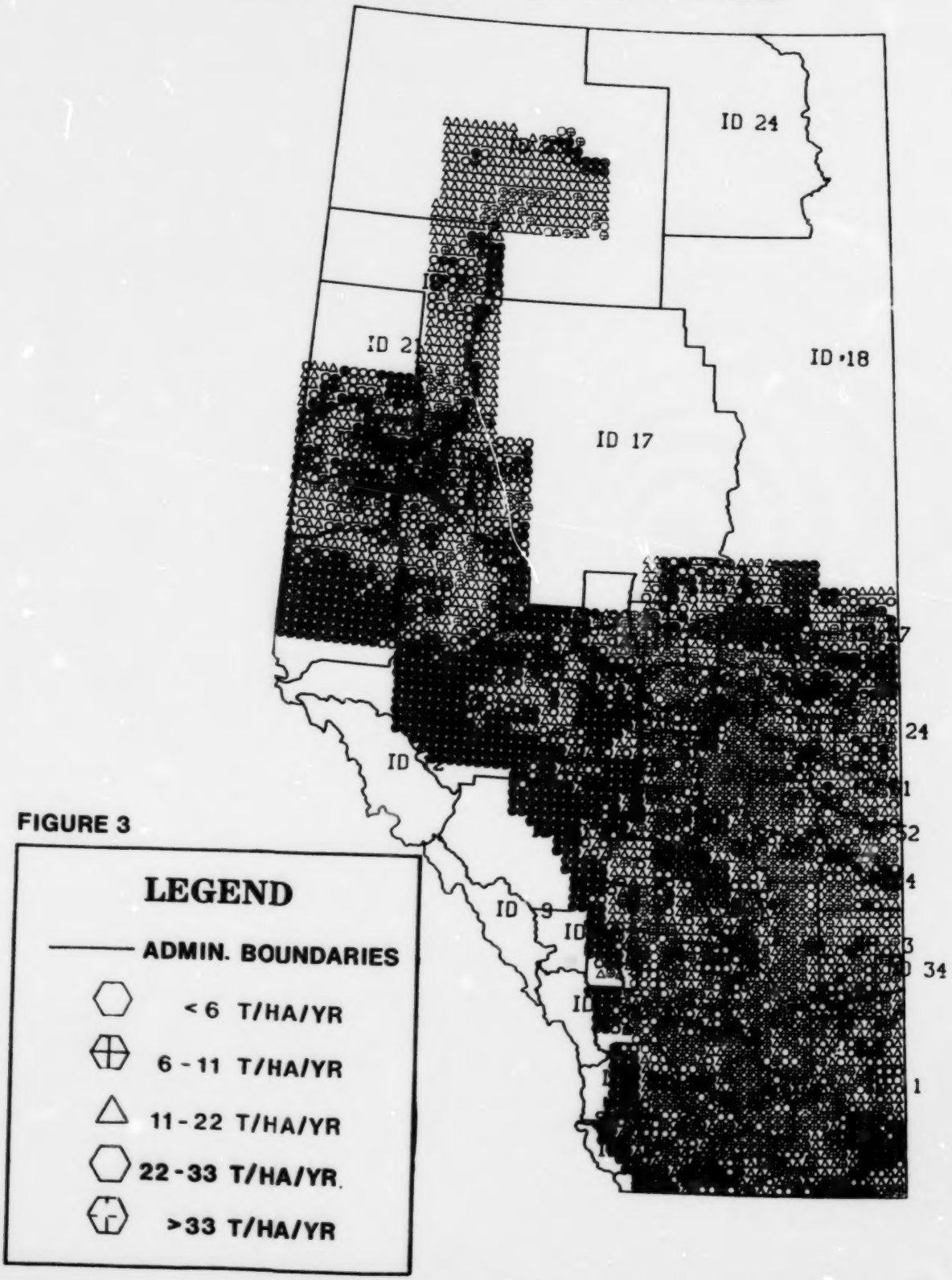

FIGURE 3

TABLE 7

WEIGHTED AVERAGE POTENTIAL COST OF EROSION[1]

Ground Cover	Cost of Erosion	Corrected[2] Cost of Erosion	Equivalent Proportion of Farm Gross Receipts[3]	Equivalent Proportion of Farm Operating Expenses[3]
	--- ($ million/year) ---		---------- (%) ----------	
None	531.6	428.7	10.8	15.9
Canola	204.0	164.7	4.2	6.1
Small Grains	154.4	124.5	3.2	4.6
Provincial Mix	111.7	90.0	2.3	3.3
Municipal Mix	108.9	88.7	2.3	3.3
Alfalfa	13.3	10.7	0.3	0.4
Poor Canopy Forest	2.4	1.9	0.05	0.1

1. Weighted by agricultural land distribution.

2. Adjusted for non-dominant soil type and slope.

3. Gross provincial farm cash receipts were 3,949 million dollars in 1984. Farm cash operating expenses were 2,694 million dollars in 1984.

   Source: Farm Cash Receipts and Expenses 1984, Quarterly, December 1985 Issue 3, Alberta Agriculture.

have to be continuously replaced by fertilizers, this could present a serious potential danger to the viability of agriculture in Alberta. Alternatively, erosion control has the potential for producing substantial savings, which could be translated to an increase in realized net income to Alberta farmers.

Examination of the distribution of the estimated cost of erosion between the regions shows that Regions 1, 2, and 3 have the potential for the highest economic loss in absolute terms (Table 8). Each of these regions represents approximately 21 per cent of the potential soil loss from agriculturally developed lands in the province. This situation is partly a factor of the relative size of these regions. Relative size also explains why Region 6, which has the highest mean erosion level for all ground cover types, has the second lowest potential cost of erosion.

CONCLUSIONS

This study presented one method of evaluating potential soil loss through water erosion under different soil cover types. The estimated soil loss in tonnes per hectare was based on currently available information. The accuracy of the results is dependent on the applicability of the USLE equation to Alberta conditions. Accuracy is further restricted by the level of detail in the SIDMAP database.

The economic evaluation was based on the value of the three major elements (nitrogen, potassium and phosphorus) removed through water erosion. This provides a fairly conservative estimate only and does not put a value on the deterioration or soil structure and other physical qualities associated with topsoil. Environmental costs are also omitted.

The time value of money was not taken into account in this study. The economic costs were reported on an annual basis assuming that the cost would be incurred in the same year that the soil loss occurred. While the value of the soil would in fact be reduced at the time of erosion, in many instances the actual economic loss in income would

TABLE 8

DISTRIBUTION OF AVERAGE POTENTIAL COST OF WATER EROSION BY REGION FOR THE MUNICIPAL CROP MIXES

Region	-- Municipal Crop Mix --[1] Cost of Erosion	Corrected[2] Cost of Erosion
	--- ($million/year) ---	
1	21.6	19.1
2	24.7	20.8
3	23.8	18.9
4	17.3	14.5
5	8.2	5.8
6	13.4	9.6
Total	108.9	88.7

1. Weighted by agricultural land distribution.

2. Adjusted for non-dominant soil type and slope.

occur sometime in the future. This is because the reduction in yield resulting from erosion can be a very gradual process, and amelioration through the application of additional fertilizers may not be done immediately. In other words, the impact on the farmer's cash flow may be deferred. Most likely, this impact will be deferred to the next generation. Also, the impact is often masked by changes in technology and management. Thus, yields may be maintained through new or additional inputs which are reflected in costs but which may not be acknowledged as being erosion-related costs.

The absolute value of the costs derived in this study may appear to be high, at 88.7 million dollars per year for the existing municipal crop mix. However, when related to the total agricultural land base this is approximately $3.00 per acre. On the other hand, this cost represents 2.3 per cent of gross farm cash receipts or 3.3 per cent of cash operating expenses. This indicates that water erosion has a major negative impact on realized net farm income through increased costs. Conversely, erosion control could have a significant positive impact on realized net incomes in the long run. While the estimated costs of erosion are equivalent to 2.3 per cent of gross farm cash receipts, realized net farm income is equal to 16.1 per cent of gross farm cash receipts. Thus, erosion or erosion control has the potential for affecting realized net farm income by about 14 per cent. If erosion loss is treated as an additional cost, then realized net farm income could be reduced by 88.7 million dollars. On the other hand, with erosion control, there is a potential saving or increase in realized net farm income of 88.7 million dollars.

As indicated previously this method of evaluation has its limitations. The main limitations rest with the representativeness of factors of the USLE and the SIDMAP database. Losses did not include nutrients other than N, P and K, and the effects on soil structure and texture were not considered. Also, losses measured were restricted to on-farm losses. There are also social losses or environmental impacts resulting from erosion. These include sedimentation in drains, irrigation ditches, reservoirs, lakes and streams, and deterioration in

water quality. Despite the limitations, the study clearly indicates that there are benefits to be derived from erosion control. The cost of such control cannot always be borne entirely by farmers and in some instances control may be out of the hands of affected farmers. The study also indicates that there is need for more improved and comprehensive methods of evaluating soil loss. There are in fact other methods of estimating the cost of erosion. These include evaluating the reduction in productivity on eroded lands compared with non-eroded lands. This type of evaluation would require a comprehensive study to estimate the yields under each condition and to obtain a more precise measure of the soil loss.